RADIO PLANNING AND PROPAGATION (V.4 November 2019)
An introduction to how radio networks are planned and the limitations associated with the technology

When planning cellular telecommunications networks engineers use specialist software to predict, with a high degree of confidence, the behaviour of cellular transmissions. This then enables the operator to calculate how many cell sites are needed to provide the level of coverage and capacity required by their customers.

Radio signals at the frequencies used for cellular radio propagate in a manner that is broadly similar to light. Generally anything that casts a shadow to light will attenuate radio waves. The strength of radio signals detected at a receiving device naturally reduces the further away it is from the transmitter. In general, the attenuation (or decay) in signal power is affected by a number of variables. The main factors are:

- signal frequency (attenuation increases with frequency),
- distance (from the transmitter),
- terrain (such as hills),
- clutter (such as buildings, foliage, vehicles, and water) and
- atmospheric conditions (such as rain).

A reduction in the strength of the radio signal increases the likelihood of dropped calls and reduced data rates for internet browsing, for example.

Clutter

Any physical object obstructing the propagation of radio signals causes a reduction in the signal strength reaching a customer's device. A common term for these objects is 'clutter'. The more obvious examples are buildings and geographical terrain such as hills and trees.

Buildings cause a varying amount of signal reduction depending on their height, construction, thickness of walls, number of windows etc. Glass causes a lower reduction in signal than brick/concrete walls.

Customers will inadvertently be aware of this by finding that sometimes they need to go near windows, a higher floor of a building or even outside in order to achieve a stronger signal for their mobile devices.

Generally, the higher the signal frequency the more it will be impacted by clutter.

Tree Clutter

The effects of trees on signal degradation can be significant. Signal absorption and shadowing effects vary according to vegetation and density, and are caused by the main tree trunk, branches, and leaves.

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Cell sites located in or near trees will have signals significantly reduced. As a result, a number of extra sites may need to be built locally in order to counter-effect this.

Signal variation throughout the seasons is also a practical concern. Leaves on trees in the spring and summer can cause shadowing and reduce radio voice quality and increase the number of dropped calls.

As a result, the bottom of an antenna should a) be above the top level of the trees, b) allow greater height due to the antenna downtilt at build or for future requirements and c) allow some room for future growth of the trees.

When a cell site utilises point-to-point microwave dishes to communicate with other cell sites in the network any obstruction between these dishes will result in failed line of sight communications. As a result, dishes need to be placed above the top level of the trees.

Propagation Models

In essence these are mathematical formulae used to characterise radio wave propagation, in order to determine the signal strength at a receiving device.

Coverage Planning Tools

Radio planning engineers plan cellular networks using highly sophisticated computer programs that incorporate propagation models. Armed with data on cell site location, cell site configuration, maps, terrain etc. they are used to *predict* areas of coverage deficiency (so called 'coverage holes'), new site requirements and configurations.

Network Changes

Over time the topography and clutter in an area may change. For example, building developments, housing and tree growth can all change. As the signals received from local phone masts can degrade, as they are dependent on these factors. These reasons along with increased usage of mobile devices, customer complaints, network consolidation (mast sharing) and new technologies (5G) require a re-evaluation of a network operator's telecommunications infrastructure.

Mast sharing can result in some masts no longer being needed. As a result, they are decommissioned and physically removed. Mast sharing will however sometimes result in the need for a taller more substantial structure.

Technical surveys undertaken for reasons above may highlight that antenna height increases are required – this is more likely for sites with low antenna heights around 15m AGL, particularly street furniture sites. More details on these reasons below.

While thus far this document is generic to mobile telephony masts it should be noted that each mast has to be dealt with on a case-by-case basis.

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Site Height increases

There are a number of reasons why an operator may request a height increase on existing structures. The main ones are described below.

Maintaining existing coverage
The antennas inside, for example, street furniture sites are generally of 2 physical build designs – 'Single Stack' and 'Dual Stack'. The former describes when the set of antennas are all at the same height. The latter describes a site with 2 sets of antennas one above the other.

The 'Dual Stack' is by far the preferred option. This is due to a number of factors including greater flexibility & control for different technologies and providing optimum service performance to customers.
Site upgrades such as network consolidation between Vodafone and Telefonica and/ or new 5G technologies facilitate a Single Stack structure being upgraded to a Dual Stack structure. In a straight swap scenario at equal height the new lower aperture antennas would be lower than they were originally - resulting in significantly reduced coverage. To ensure existing coverage is maintained the whole structure needs to be increased in height.

Clutter changes

A more extreme example is when the local clutter or tree lines have changed, or are such that the mobile signals are blocked, resulting in lower quality calls and downloads for mobile device users. To provide sufficient services to customers height increases on existing masts or additional new masts are required. The former is the preferred option in many cases.

5G Technologies

5G New Radio technologies operate in higher frequency bands than older technologies. Since it operates at higher frequencies where attenuation of the radio signal is naturally higher, and the effects of clutter are greater it will normally require a higher structure to achieve the same coverage footprint. Furthermore, unlike traditional technologies 5G uses adaptive beamforming technologies to increase capacity and data speeds to the user. For effective beamforming the antenna will normally need to be mounted higher than conventional antennas. These factors drive a require for an increase in antenna height in 5G

International Commission on Non-Ionizing Radiation Protection (ICNIRP) Compliance
The addition of new technologies and mast sharing affects ICNIRP compliance, one of the health and safety requirements for a cell site, a higher minimum mast height is required in some cases.

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